Manufacturing Guidelines of Production Design
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Lecture-29
Design Guidelines of Welding

Namaskar friends, welcome to session 29 of our course on manufacturing guidelines for product design. So, what we are doing for the last 1 week we are trying to focus on the guidelines that we must follow as product designers for parts which have to be joined together. So, in the last week our focus has been on adhesive joining, mechanical fastening as well as we have seen that what are the product design guidelines that we must keep in mind for parts to be joined together.

And if you remember we have seen in the very first session that first session for this week I am talking about. In this week that is session number 26 we talked about the various types of joining processes. We have seen that we can make a permanent joint using the welding process, we can make a temporary joint using the mechanical fasteners or we can use the adhesive bonding for different types of or combination of materials.

So, we have seen for adhesive joining what are the guideline, for mechanical fastening what are guidelines. Today our target is to study the guidelines for welding and as all of you are well aware that welding is the most commonly used joining technique for metals. So, whenever metallic parts have to be assembled together either we will go for welding or we will go for mechanical fastening through different types of rivets or the threaded fasteners.

So, we have seen regarding rivets and threaded fasteners what are the guidelines, today our target will be to learn the guidelines for the welded joints. Because many times we will design the parts and these parts maybe required to be assembled in order to get the final product. So, how the part configuration or the part geometry must be modified to make it more applicable for welding process, to make it more suitable for the welding process.

So, many times we will see in the images of the diagrams of the figures that will cover today. We will sometimes we have a tendency to join the 2 parts together we do not think about the cross-section of the 2 parts. Now one part maybe very thick in cross-section another one maybe thin, so when we are trying to join them together there maybe some problems related to welding. Now this some problems can be distortion maybe one reason there can be unfilled weld bead geometry.

So, there can be different types of defects that may take place because of non-uniform nature of the 2 adherents or 2 parts or 2 weld pieces which are to be joined together. So, 2 work pieces that have to be joined together, so this is just one standard guideline that we must keep in mind that the 2 cross-sections that we are joining together. If possible we must try to make them of the similar cross-section or similar thickness.

So, that is just one guideline, there are hundreds of such guidelines which we must keep in mind when we are designing the parts which have to be welded together. So, there can be some modifications required in the part geometry which have to be joined together using the welding process or there maybe some modifications in the procedure or the process which we are taking and the process in this case is welding.

So, from welding point of view what modifications we can do in order to avoid these defects is not the target of our discussion. Because that is also very important issue but our target area is that when we are designing a part, the product has to be made in 5 or 6 different parts. And these parts have to be welded together using any standard welding procedure, for example the electric arc welding or the friction welding or the other fusion welding techniques like MIG and TIG.

So, there are different types of welding processes, so we when we are designing a part we must keep in mind that how these 2 parts will be joined together. And when they have to be joined together what things or what guidelines, what criteria we must keep in mind while designing these parts. So, that is the basic background of what we want to discuss in this short lecture of 25 to 30 minutes, so let us now start with the very basic definition of the welding process.

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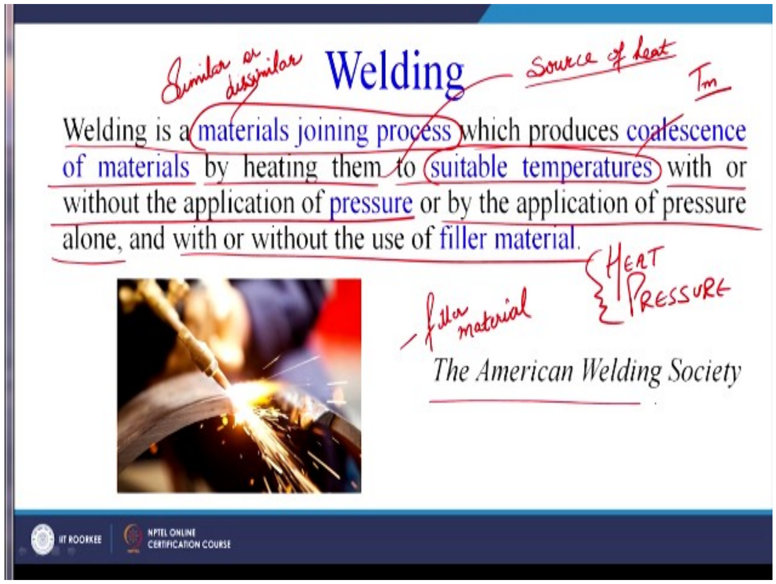

The welding is a materials joining process, so we can see welding basically is a materials joining process. So, these materials can be similar or these materials can be dissimilar, so we may have the 2 parts that we want to join together made up of similar materials sometimes they maybe of different materials also. So, we have to join these 2 materials together which produces our welding process produces a coalescence of materials.

So, the fusion of the 2 materials will take place upon the welding process, how the coalescence will take place by heating them, so we need to have a source of heat also. Now this source of heat in case of welding can be either generated through a electric arc or it can be generated through a laser or it can be generated through ultrasonic vibration. So, if the source of heat can be and either it can be in case of gas welding we have combustion of gases which produces the heat.

So, one is source of heat also is important in welding, so what we need to do it is a materials joining process which produces coalescence of materials by heating them, how much heat to suitable temperatures. Many times we may go above the melting point of the materials to be joined sometimes we may go below just below the melting point of the materials to be joined, so that depends upon the type of welding process that we have chosen for making the welding or for making the weld joint.

So, we have to understand that what will the temperature for the metals that we are going to join together and what is the process that we have chosen. Now first thing input is the heat second input is with or without the application of pressure. So, we have 2 inputs here most important one is the heat another one is the pressure, so both these inputs either maybe applied independently or in synergy or in conjunction to each other.

So with or without the application of pressure or by the application of pressure alone with or without the use of the filler material. Now depending upon the type of welding we are doing for example, especially in case of gas welding many times we use a filler material. So, the filler material is also an important input that usually we take when we are making a welding process.

So, depending upon the type of process that we have chosen either we will use heat without pressure then in another case it can be heat plus the pressure, in another case it can be pressure alone. So, these are heat and pressure are the most important inputs and the secondary input sometimes in special cases maybe the filler material also. So, basically the 2 materials that we have to join together we will bring them together, we will apply heat at the joint we may or may not apply the pressure at the joint and then we will allow the joint to be formed.

Now we have to see that these 2 parts when we are designing these 2 parts what are the things that we must keep in mind. So, that our welding becomes easier or the joining of the parts become easier using the welding process. So, the basic we can see definition of welding is clear this is given by the American welding society.

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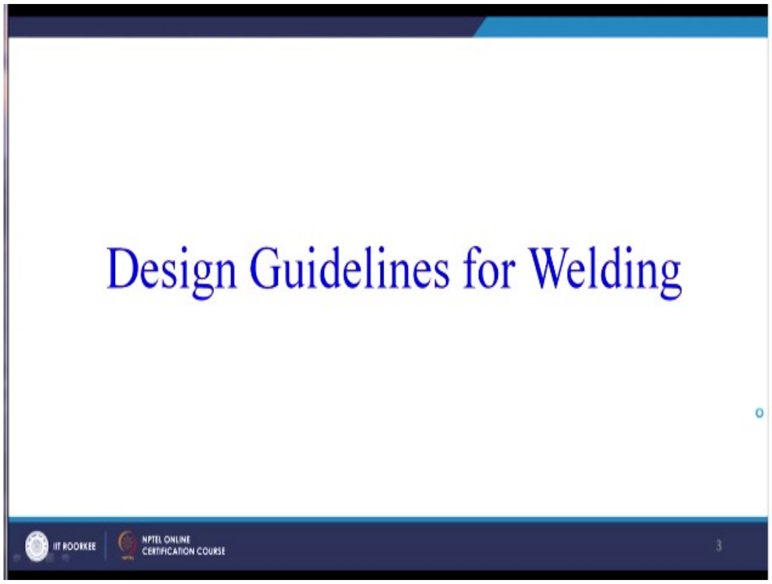

Now let us see what are the design guidelines for the parts to be joined by welding process.

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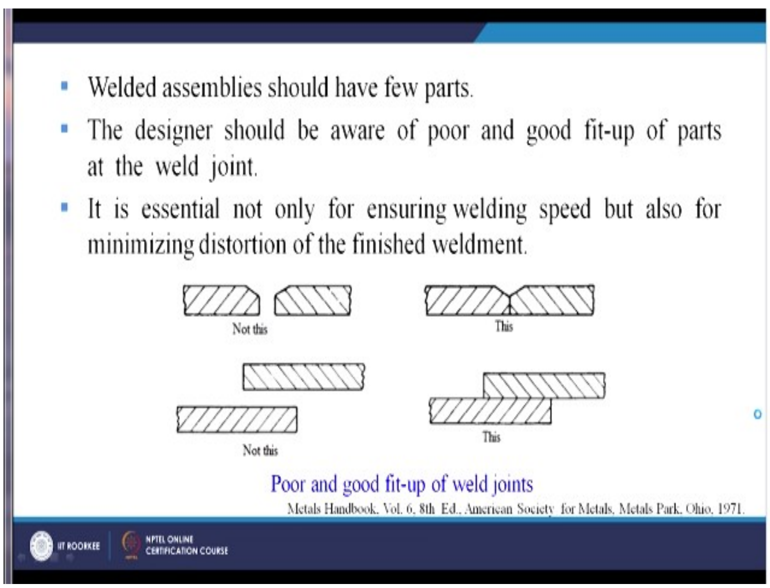

Now this is the guidelines we can go one by one welded assembly should have fewer parts. So, if you remember we have already seen in our discussion on DFA and DFM. That is design for assembly and design for manufacturing, we must try to have minimum number of parts or minimum number of joint in our product design. And we must always try to have modular designs that is the catch word these days.

So, we must try to minimize the welding why because the weld joints sometimes are prone to failure because of the different types of welding defects that may create in. So, in nutshell as a rule of thumb we must try to minimize the number of joints but in many cases depending upon the requirement the joints becomes inevitable they are necessary. So, therefore we have to design the part in such a way that it becomes easy for welding.

So, there are 2 things first thing is we should try to restrict the use of joints then wherever the joints are necessary they are maybe inevitable in those cases we must try to design our parts in such a way that it becomes easier for us to weld them or join them at a later stage. So, the designer should be aware of poor and good fit up of parts at the weld joint. So, poor fit up and good fit up examples are given this is a poor fit up these are the 2 parts that have to be joined together 1 and 2.

And this is the place where we plan to deposit our weld bead or we want to do the welding. So, this is poor fit up lot of gap is there between the parts to be joined together, so this is not recommended. Similarly you see there is lot of gap here when we want to do the welding, this is also not recommended, this is a part number 1, this is part number 2, these 2 parts have to be joined together.

So, whatever is given this side is not recommended but what is recommended we can see this type of joint preparation or edge preparation we may call it edge preparation, this is something which is advisable. So, this is something which we will we can easily deposit a weld bead here and we will be able to make a very good joint. And similarly here also if you want to do the welding or we want to do the welding here we will be able to do better welding because of the gap that is we are providing or the fit up that we are providing.

So, this is representing the poor fit up and this is representing the good fit up, so the designer should be aware of the poor and good fit up of parts at the weld joint. So, this is our weld joint, it is essential not only for ensuring the welding speed but also for minimizing the distortion of the finished weldment. So, how this good fit up is beneficial, good fit up in these 2 cases is beneficial in ensuring the good welding speed our productivity will be good and minimizing the distortion.

So, we will be able to make the weldment without any distortion there will be not be a tendency of the weld parts to come maybe get distorted at the point of welding. So, if we are able to fit up the 2 parts to be joined together properly we can easily avoid the problem of distortion as well as we can make our joints more productively in a time efficient manner. So just a very simple guideline for the parts to be joined together.

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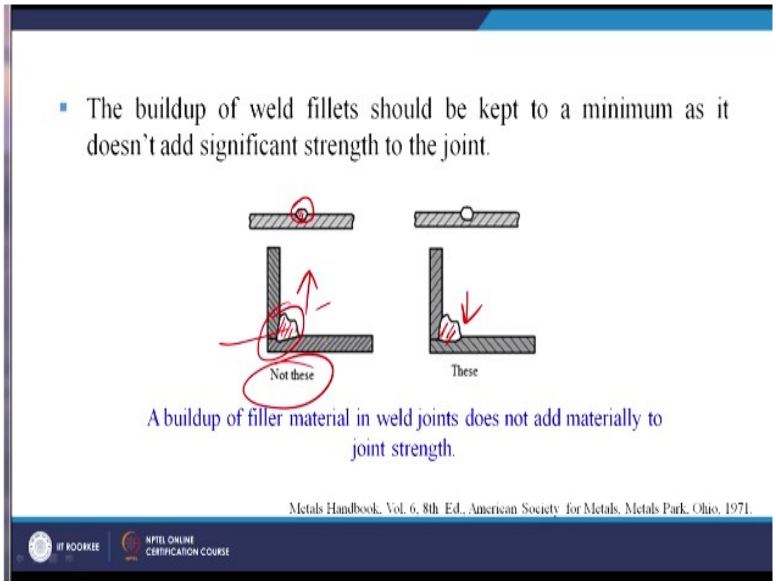

Then the buildup of weld fillets should be kept to a minimum as it does not add significant strength to the joint. So, this portion this is what we are talking about the buildup of weld fillets. Similarly this also this is maybe less this is more, so this is not recommended this is recommended. The buildup of weld fillets should be kept to a minimum as it does not add significant strength to the joint.

So, this portion is not giving any significant improvement in the strength of the joint. So, therefore there is no point in building up at the joint area. So, a buildup of filler material it is clearly written here in blue color a buildup of filler material in the weld joints. This is the buildups which is shown here buildup does not add material to the joint strength. So, it does not help us in improving the joint strength, so we should restrict this build up to the minimum possible.

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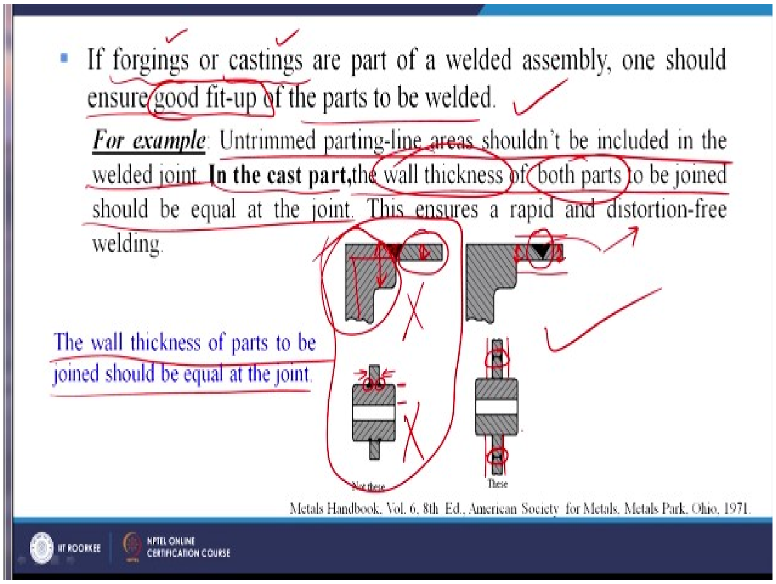

If forgings or castings are part of the welded assembly because we have seen that welding is going to be use for joining the 2 or 3 different parts together. Now these 2 or 3 different parts may have been made by different processes 2 of them are mentioned here forging or casting. So, the parts that we are joining together or individually made by either by forging or by casting, so if forgings or castings are part of the welded assembly one should ensure good fit up of the parts to be welded.

So, this is already we have seen in the previous to previous slides that good fit up of parts must be ensured when we are going to do the welding. Now the example as given untrimmed parting-line area should not be included in the welded joints. So, wherever the part when we are doing the matched die type of manufacturing. So, always there is a parting line all around the part, so untrimmed, so those parting lines have to be remove we can take a very simple example.

The plastic bucket that we take to the washroom for taking a bath you can see there will be line around the bucket. So, what is that, that we can call as a take an example of a parting line, so whenever we are welding together. So, untrimmed parting line areas, so wherever this line has not been trimmed properly, so those areas must be avoided for placing them at the welding position.

So, untrimmed parting line area should not be included in the welding joint or the welded joint. So, this must be avoided from the welded joint these parting line areas around the forgings. In the cast part the wall thickness of both parts to be joined should be equal at the joint. I have in the very beginning told that if there is a thicker part and there is a thinner part and we want to join them together there maybe some problems in terms of distortion or in terms maybe we are residual stress is that maybe developed, so all these have to be avoided.

So, what we can do, we can do that we can make the sections of the thickness same at the point of welding. So, especially in case of a cast part the wall thickness very important parameter wall thickness of both parts that are joined together to be joined should be equal at the joint. This ensure the rapid and distortion-free welding, so now here you can see this is one part this section is one part and this is another part, this have to be joined together.

So, it is not recommended because at the joint this is the joint being formed, this is a joint. So, one area is this much and another area is this much, so this is not advisable. So, when we are designing the parts we must take care that the joint must be like this. Now this is section or thickness being joined with an equal thickness, so thickness is same, so the joint will be distortion free which is already mentioned here.

So, here also we can see we are doing the welding here, so this is more than this thickness, so what we can do we can make the joint here like this and here we see the section thickness is constant. So, here also the section thickness is constant, welding is being done here so the wall thickness of parts to be joined should be equal at the joint. This is the guiding principle that the wall thickness of the parts to be joined should be equal at the joint 2 examples are given.

So, these 2 are not recommended because unequal thickness we are trying to weld together, so this is the wall thickness is same here also and in this case also wall thickness is same.

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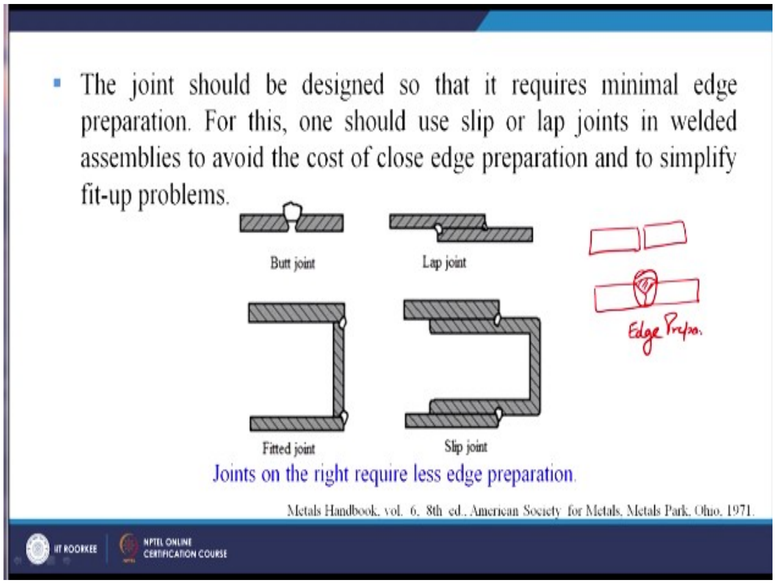

Now let us see another guideline the joint should be designed, so that it requires minimal edge preparation. So, edge preparation we can see that if these 2 parts have to be joined together, so there is no edge preparation by now. But then once we have to join the 2 parts together we can do the edge preparation like this. So, this edge has been prepared for the welding process, so this we mean this is the meaning of edge preparation.

And we can have different types of maybe edge preparations which can be done we can a single bevel double bevel. We can a single U double U, single J, double J depending upon the requirement we can have different types of preparations here. So, we can have the joint should be designed, so that it requires minimum edge preparation. So, we must try to avoid this edge preparation because it adds another maybe process to the overall process of the welding cycle.

So, the joint should be designed in order to avoid the edge preparation or minimize the edge preparation. For this one should use slip or lap joints in welded assemblies to avoid the cost of closed edge preparation and to simplify the fit up problems. So, if we are using these 2 types of joint which is mentioned here maybe slip or lap joints, so we can avoid the cost of edge preparation which is advisable and it will simplify the fit up problems.

So, we know we have seen that it sometime it becomes difficult to fit up the 2 parts together, so if we design our part in such a way that no edge preparation is required it will become easier for us to weld the 2 parts together. So, here you can see this is a butt joint, so here the fit up is not proper there is a gap here. So, this is somehow are not recommended, so here also this type of a joint and this type of a joint are not recommended, so may lead to certain problems.

But on this side we see we have a lap joint this type of joining will be useful, so the joints on the right require less edge preparation. So, these 2 joints this one and this one this require less edge preparation already we are placing the 2 parts in the lap position and we are doing the welding here, no edge preparation is required. But similarly when we are this type of assembly we can make the welding process at these 2 positions.

So, this is a kind of a slip joint which we can use for making the joint between the 2 part, this is the first this is the second part. So, we can join them using this type f configuration at this point, so not much edge preparation is required. So, when we are designing a product in which the 2 parts have to be joined together using the welding process we must try to see that additional edge preparation can be avoided if possible.

In many cases you have to make up butt joints, so you cannot help it then in that case edge preparation becomes necessary.

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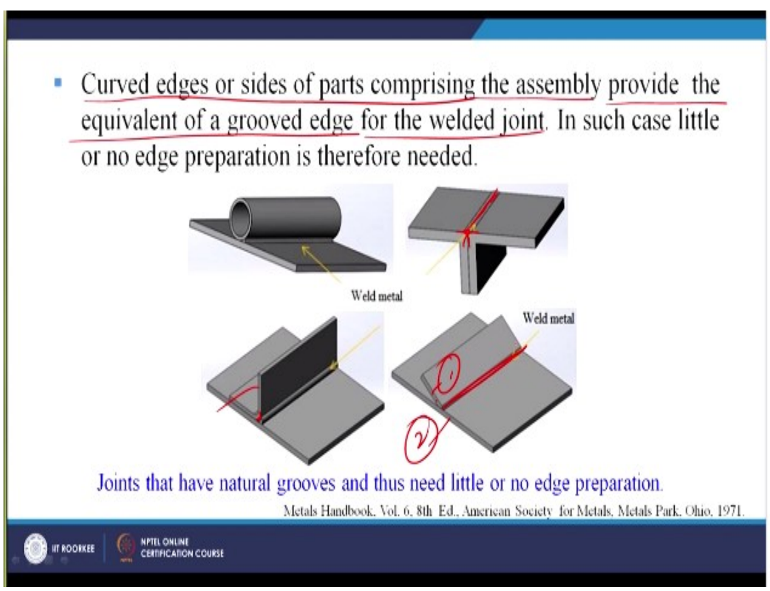

Now this is another important guideline curved edges or sides of parts we can see this is one side of part, this part, this is the part. So, curved edges or sides of parts comprising the assembly provide the equivalent of a grooved edge for the welded joint. So, here we can see this is one part this is another part, so automatically we get a natural groove here across which we can do the welding.

Similarly this part and this part this is part number 1, part number 2, so these 2 parts have been done we get a natural groove here which we can use for welding. So, wherever possible we must take advantage of this natural groove. So, here also we can see this is round, so here we get a natural groove across which we can do along with sorry we can do the welding. So, in such cases little or no edge preparation is needed or required.

So, in the previous slide we have seen that we must design the joints in such a way that minimum edge preparation is required and this is one advantage of the naturally occurring grooves of naturally designed grooves which will help us or provide us a maybe a direction along which we can do the welding operation. And we get the natural we can say geometry across which we can deposit the weld bead.

So, the joints that have natural grooves and thus need little or no edge preparations the examples are given here. So, you have a natural maybe this is the maybe on the exaggerated skill slightly I am showing this part needs to be welded to this part. So, this is the point where we are getting the natural groove, so we can deposit our weld bead here. So, this is going to be helpful for us, so whenever we are designing a part we must take advantage of the natural grooves for our welding process.

And in many cases we have seen that we must avoid the sharp corners in previous discussion for various processes we have seen that sharp corners must be avoided. So, if sharp corners must be avoided we must give a radius at the edges, so that radius can be used when that part has to be joined with another part. So, we get a natural groove and along the natural groove we can do the welding process.

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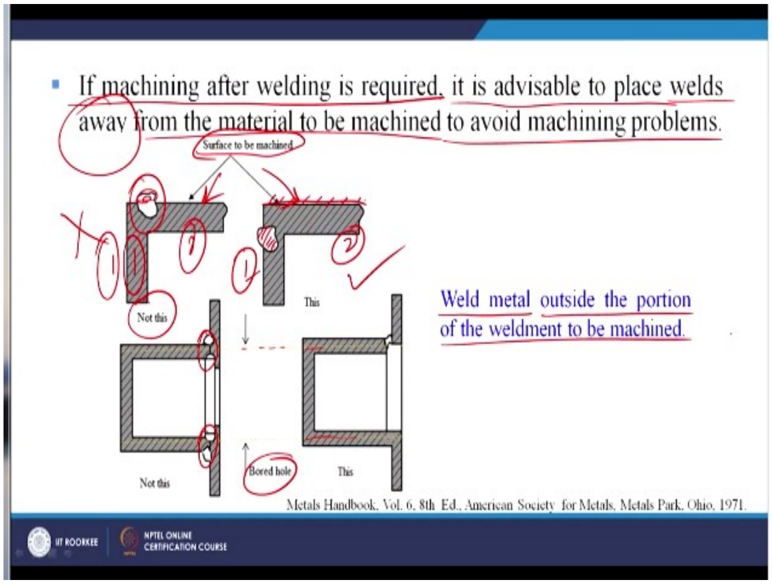

Now another important guideline if machining after welding is required because all these processes will be done for ensuring assembly of our product. So, if machining after welding is required it is advisable to place the welds very important, it is advisable to place the welds away from the material to be machined to avoid machining problem. So, when we have to do the welding on a particular surface we need to do the machining also at a latest stage.

The weldment or the weld bead must be placed away from the machined surface, so here we can see this is a part being joined part number 1 being joined to part number 2 and this is the weld bead which has been deposited. And this is a surface, this surface has to be machined and this surface has to be machined, so this is not recommended because we have to machine this surface and we have a weld bead here, so it will cause a problem.

So, what we can do, we can do the welding here join this part number 1 to part number 2 and then later on this surface we can do our machining. So, this is advisable similarly here we are doing the welding here and this is the board hole we need to make a hole across this thing, this is other line shown here. So, the boring has to be done, so we must do the welding away from the area where the boring has to be done.

So, the weld metal outside the portion of the weldment to be machined, this is important. That we have to make our welding away from the area where machining is to be done.

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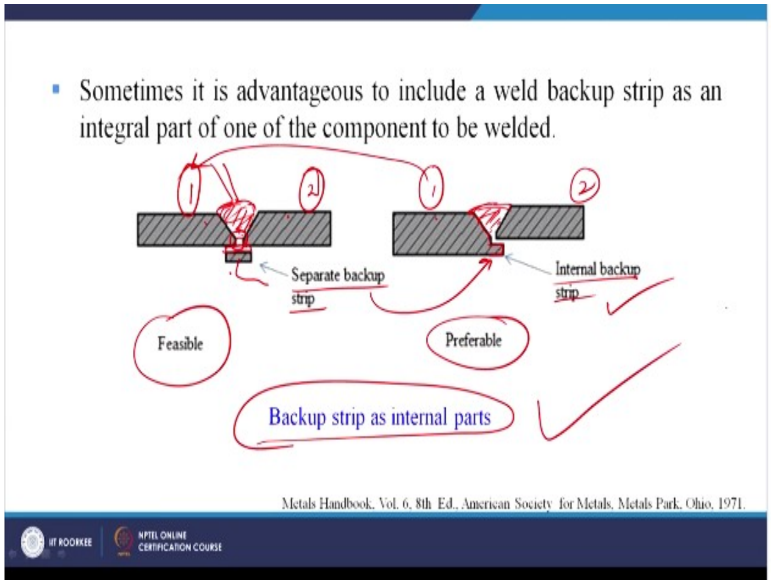

Again sometime it is advantageous to include a weld back up strip as an integral part of one of the components to be welded. Now this is component number 1, this is component number 2, so these 2 have to be welded together. So, we can make a separate backup strip here, so this backup strip can be placed here, so that when we are doing the welding operation in this zone. Our metal is concentrated or weld pool is created here, so this backup strip can be use.

Another modification can be that this backup strip can become an integral part of one of the parts to be joined together. So, part number 1 geometry you can see here, here it is simple geometry but here little modification the internal backup strip has been made the integral part of part number 1, part number 2 remains same. So, when they fit up properly we can do our welding in this area.

So, therefore little modification in the product design can help us to make a better welded joint which will have good strength which will be distortion free as well as failure proof. So, we can do the modifications maybe judiciously in order to make a good welded joint, this is also feasible in many places we will use a separate backup strip in. but it is always advisable what is preferable is the internal backup strip because here 3 parts we have to control.

Here only 2 parts are there and integral strip is a part of the one of the pieces to be joined together. So, backup strip as internal part this is a major guideline that we must keep in mind. Then this is again a reputation of what we have already covered quickly I will read this.

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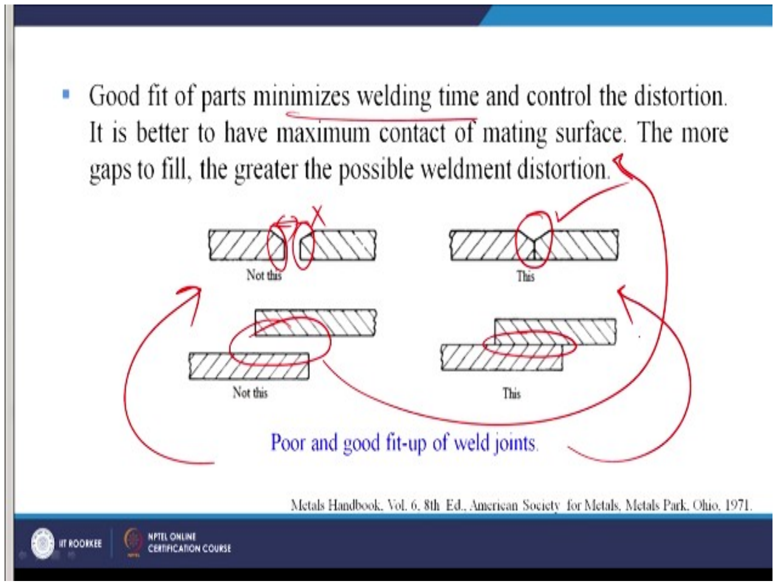

Good fit of parts minimizes the welding time as we have seen it ensures good welding speed and control the distortion. Already we have covered in today's session only just a revision it is better to have maximum contact of the mating surfaces. So, these are the 2 mating surfaces which have to join together, so we must ensure the maximum contact between the 2 here. There is lot of gap which needs to be avoided, the more gaps to fill the greater the possibility of weld distortion.

So, more gap to fill, more is the probability of weld distortion, lesser gap better welded joint. So, poor and good fit up of the weld joints is shown this is poor fit up and this is the good fit up.

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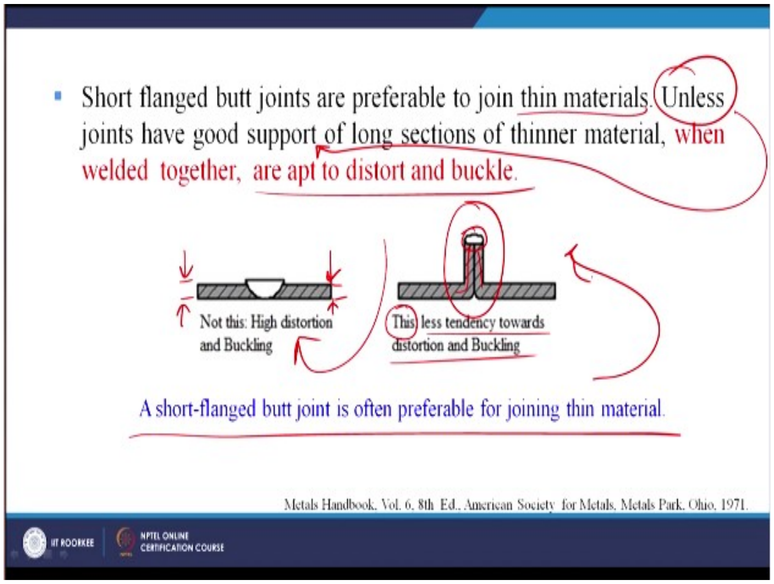

Now let us see when we have to join very thin sheets of metal, so short flanged butt joints are preferable to join the thin materials. So, whenever a thickness is less we can see here these are the parts to be joined together and the thickness is comparatively lesser. So, short flanged butt joints, so this is recommended less tendency towards distortion and buckling. So, we have a short flange here and here we can do our welding, short flanged butt joints are preferable to join thin materials unless joints are good support of long sections of thinner material.

This is being talked about when weld together or up to distortion and buckle, so unless is very important unless you can ensure good support of long sections of thinner material. If you do not provide that kind of support the joints are prone to distortion and buckling which is shown here high distortion and buckling, a short flanged butt joint is often preferable for joining of the thin material as is shown here less tendency towards distortion and buckling.

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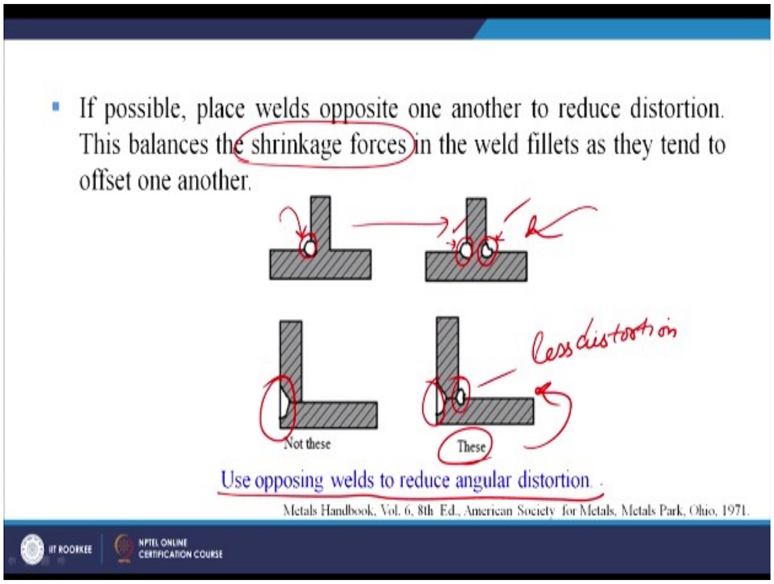

Now this is another important guideline, if possible place welds opposite to one another to reduce the distortion. So, here we are doing welding only in this area but it advisable that we can do it in both the areas here, why. Because this balance is the shrinkage forces in the weld fillets as they tend to offset one another. So, the shrinkage forces are balanced when you do in both the sides of the weld or the weld profile.

So, here this is on one side only there is tendency of the maybe distortion that may take place but if you balance it on both sides less distortion you will notice, so less distortion. So, we can see that these are the recommended joint configurations this is something can be avoided because then shrinkage force is may lead to distortion, use opposing welds to reduce the angular distortion. So, we can see that we can weld on both sides to ensure a distortion free joint.

So, basically we can see that there are number of other such guideline these are the most simplistic type of guideline just where looking at the diagram you can easily understand that yes this will be somehow beneficial. So, number of such guidelines have been listed and these guidelines if we take care during our designing process when the parts are being designed which have to be welded later on.

If we keep in mind these guidelines ensure the uniform thickness of parts to be joined make the welding away from the surface where machining has to be done. So, if we take into account all these guidelines we will be able to design the product or the parts of the product in such a way that we will have absolutely no problem when we are going to join them properly. Let us quickly have a understanding of some more guidelines before we windup for today.

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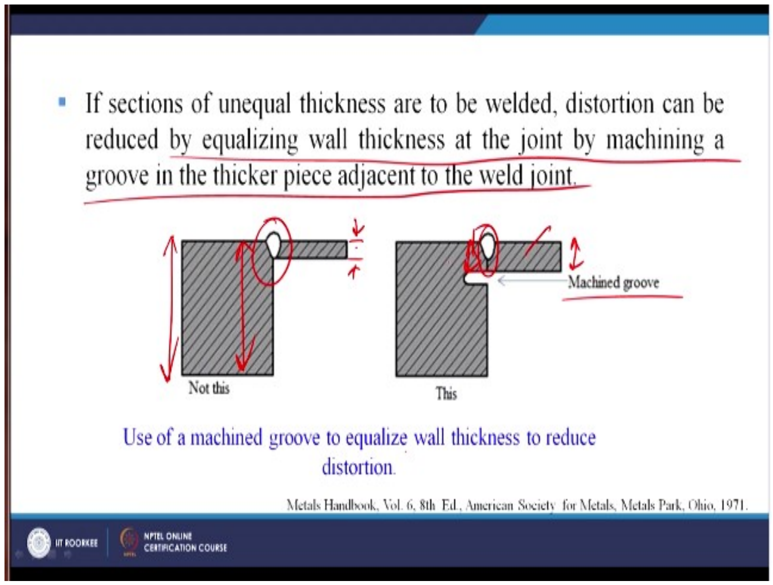

If sections of unequal thickness are to be welded which we have already discussed, distortion can be reduced by equalizing the wall thickness, this we have already taken in the beginning of today's session. So, we must equalize the wall thickness at the joint by machining a groove in the thicker piece adjacent to the weld joint, how we can do this. Here we can see this thickness is considerably high and this thickness is considerably less, so we are joining them here.

So, what we can do, we can machine a groove here, now this thickness is equal to this thickness, this is part to be join to this part. But thickness at the joint is same, so use of machined groove to equalize the wall thickness to reduce the distortion. This guideline already we have seen, now here the solution also is provided that we can make a machined groove to ensure that the thickness is constant or uniform.

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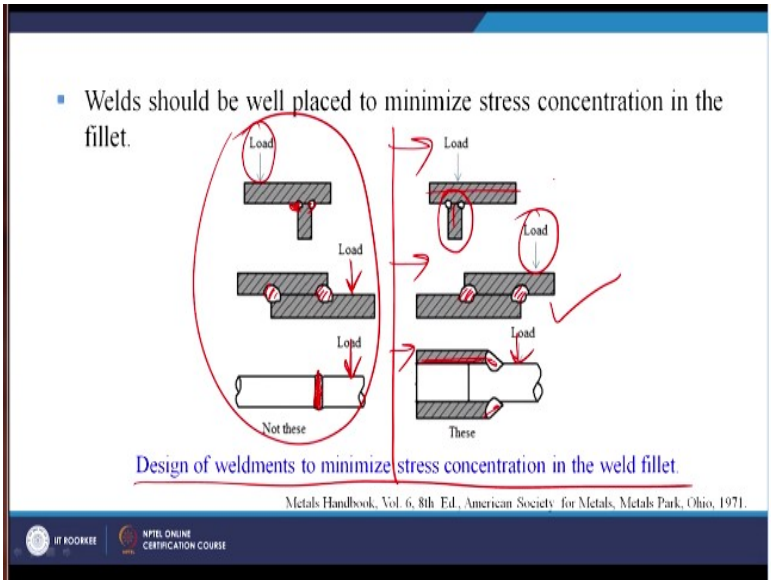

Again we can see weld should be well placed to minimize stress concentration in the fillet, so we have to see that where the welding has to be done. So, here we can see this is the load that is acting and this is the welding that we are doing at 2 places. So, this is something which is not recommended, so when the load is acting here it is always better to place your 2 sections in this manner because the load bearing will be better well should be well place to minimize stress concentration in the fillet.

So, if we load it here there will be stress concentration here but if we load it here it will be able to bear the load in a more efficient and effective manner. Similarly we can see this is the place where the welding has been done and here the load is acting it is not recommended. So, what we can do we can design it or redesign it in such a way that when the load is acting here this is the right joining process that we must follow.

Similarly there we can see this is the joining which has been done or the welding which has been done and the load is acting at this point. So, what we can do we can join it like this, so that and here the load is acting, so we see that all these 3 configurations are better load bearing configuration. They can absorb the load in a much better manner or take the load in a much better manner as compared to these 3 configurations.

So, there is not much that has changed but slightly we have used our common sense as well as we can this can be explained, this can be done , this can be tested with the help of standard FP package is the load is acting. And then we can discretize the whole structure into the finite element and then apply the load and see that which configuration is better. So, we are not going to going to that much analysis part but these are the standard guidelines that we must keep in mind.

That wherever the load is acting we have to see that how and where our welding must be done or where our joint must be placed, so this is related to the placement of the joint. So, weld should be well placed to minimize the stress concentration in the weldment. So, design of weldments to minimize stress concentration in the weld fillet. So, this is something which is better, this is these 3 design configurations are better as compare to these 3.

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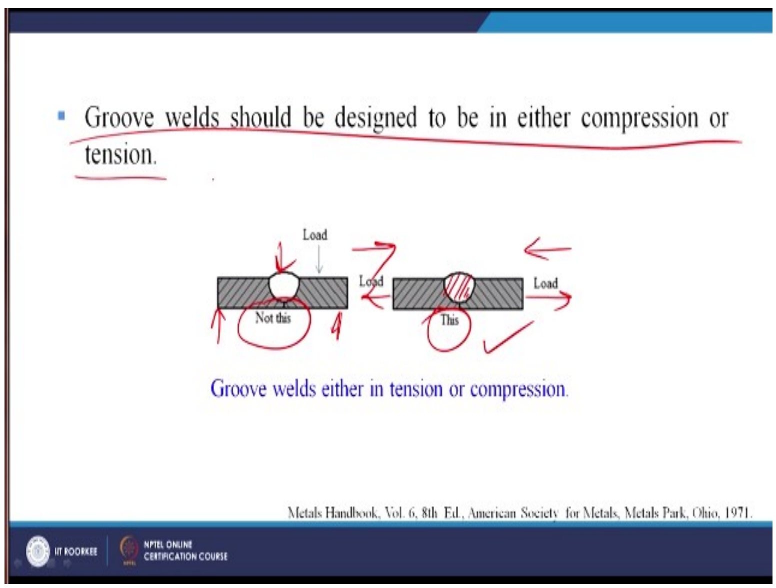

Now let us see the grooves weld should be designed to be either in compression or tension. So, here we can see this is our welded joint and here the load is acting, so it is not in tension or compression. So, this is something which is not recommended but here we can see this is our weld bead profile and the loading is in this direction, tension or it can be in compression also this is what is recommended.

So, groove welds either in tension or compression, so that is what we must ensure and here maybe if it is supported from here it is a kind of a bending problem that we are doing. So, we must ensure that groove welds should be design either in compression or in tension. So, basically we have tried to highlight today that when we are designing the parts which are to be joined together we must take into account that where the welding has to be done, what type of load is going to act on the part.

And then we must take into account that the positioning of the weld bead plus we can say the uniformity in the thickness of the parts to be joined together. Machining of a groove to ensure the uniformity of the part thickness where the welding has to be done. So, if we take care of all these guidelines in nutshell we will design our part which will be easily weldable and that will reduce the failure rate or the defective parts being produced and our product development cycle will be quick and effective.

So, with this we conclude the today's session we have very briefly try to highlight the guidelines which must be kept in mind when you are designing a part which has to be welded. In our last session for this week that is week number 6 we will try to talk about by brazing and soldering which are other 2 joining processes that are used for joining the parts.
Thank you.